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Evaluation of New Tools for Determining Crop Nitrogen Status and Availability

Bob Wiedenfeld

Texas A&M University Research and Extension Center, 2415 E. Highway 83, Weslaco, TX 78596

ABSTRACT

Supplemental nitrogen fertilization is required for optimum crop growth, but there are no rapid on-farm techniques to assist the grower in determining how much N to apply in South Texas. The Minolta SPAD 502 Chlorophyll Meter and the Cardy Nitrate Meter are affordable, hand-held, easy-to-use tools which could be of value by providing an estimate of plant N nutrition status or soil N availability. These instruments were evaluated on a sugarcane nutrition study on treatments that were expected to exhibit substantial responses to added N. Neither instrument indicated any differences in plant N nutrition status in the spring when only limited growth had occurred, probably because so little N had been taken up by the plant up to that time. Later sampling would be too late to be of assistance in making fertilizer decisions. The Cardy Nitrate Meter also failed to detect differences in soil N availability due to 0, 60, 120 and 180 kg ha^{-1} of supplemental N fertilization, even though such differences were detected by a more sophisticated analytical procedure. Sample-to-sample variability in the Cardy measurements apparently reduced the usefulness of this instrument for detecting soil N differences.

RESUMEN

Aunque los cultivos requiren fertilización complementaria de nitrógeno para su crecimiento óptimo no existen técnicas rápidas en campo para ayudar al productor a la determinación de la cantidad de N a aplicar en el sur de Texas. El medidor de clorofila Minolta SPAD 502 y el medidor de nitratos Cardy son herramientas manuales de costo accesible y de fácil uso que podrían ser útiles para proporcionar una estimación del estado nutricional de N en la planta y de la disponibilidad de este elemento en el suelo. Estos instrumentos fueron evaluados en un estudio nutricional en caña de azúcar sometida a tratamientos en los que se esperaba la exhibición de respuestas sustanciales al N añadido. Ningún instrumento indicó diferencias en el estado nutricional de N en la planta durante la primavera cuando solamente había ocurrido crecimento limitado, probablemente porque muy poco N había sido tomado por la planta hasta ese momento. Muestreos posteriores serían demasiado tardíos para ser de ayuda en la toma de decisiones con respecto a la fertilización. El medidor de nitratos Cardy tambien falló en la detección de las diferencias en la disponibilidad de N en el suelo debidas a la fertilización complementaria de N a 0, 60, 120 y 180 kg ha^{-1} aun cuando dichas diferencias fueron detectadas por un procedimento analítico más sofisticado. La variabilidad entre muestras en las mediciones Cardy aparentemente redujo la utilidad de este instrumento para detectar las diferencias de N en el suelo.

Additional Index words: Minolta SPAD 502 Chlorophyll Meter©, Cardy Nitrate Meter©, sugarcane, Saccharum officiinarum L.

Nitrogen is the major plant nutrient most often deficient for crop growth in the Lower Rio Grande Valley of Texas, and substantial effort and expense are required to satisfy crop demand. Nitrogen also undergoes numerous transformations and movements as it cycles through the plant-soil-water system. Soil tests and other measures of N availability have thus far not given a reliable indication of the need for N fertilization in this subtropical environment. Furthermore, soil and tissue sample analyses or mineralization indexes which could possibly be developed as indicators for fertilizer recommendations are time consuming and expensive to perform and results lack timeliness. Growers therefore typically rely on past experience with a particular field and their own common sense to determine how much N fertilizer to apply. Excess N is often used in order to insure that this nutrient does not limit crop growth, which is potentially wasteful and can become an environmental contaminant.

Recently, relatively inexpensive instrumentation has become available which could provide assistance in determining how much N fertilizer is needed for optimum crop growth. The Minolta SPAD 502 Chlorophyll Meter (Minolta Corporation, 101 Williams Drive, Ramsey, NJ 07446, USA) is a hand-held easy-to-use photometer which provides values generally well correlated with leaf chlorophyll content. Chlorophyll content, and hence the green color of leaves, is directly related to N status of a plant since N is an essential component of chlorophyll. Studies have shown good correlation between SPAD (Soil Plant Analysis Development) units and the N content of leaves for several crops including corn (Wood et al., 1992), cotton (Edmisten et al., 1992), rice (Turner and Jund, 1994) and wheat (Follett et al., 1992). Relationships have also been shown between chlorophyll meter readings, N application rates and crop yields (Minotti et al. 1994). A good correlation was found between SPAD readings and rate of N fertilizer application on cotton in the Lower Rio Grande Valley (Wallace, 1997). However, these studies have also found that numerous factors other than plant N status also affect SPAD readings including position within the leaf, leaf age and location of the selected leaf on the plant, crop moisture status, crop growth stage, cultivar, and season.

The Cardy Nitrate Meter by Horiba Instruments (1021 Duryea Ave., Irvine, CA 92714, USA) is a hand-held easy-to-use ion-specific electrode meter which measures the NO_3^--N content in fresh plant sap or in a soil extract. Petiole NO_3^--N has been shown to be a good indicator of plant N status (Joham, 1951; Wallace, 1997), but recent investigations of sap NO_3^--N readings as an indicator of plant N nutritional status, primarily cotton, have met with mixed results (Constable et al., 1991). Kubota et al. (1996) demonstrated a good relationship between Cardy petiole sap NO_3^--N and dry petiole NO_3^--N, suggesting that the Cardy Meter could replace the established procedure based on dry petiole NO_3^--N as an indicator of N requirements for cauliflower in Arizona. A petiole sap N quick test based on the Cardy Nitrate Meter is being recommended based on numerous studies over a 10 year period as an effective tool for determining N sufficiency status of numerous vegetable crops in Florida (Hochmuth, 1994). Analysis of the N status of soil samples offers the potential to assess nutrient availability well before it is detectable in plant tissue, and can therefore be corrected much earlier in crop growth. Again, time and cost of laboratory procedures along with questionable reliability of the recommendations based on such methods have hindered their use in this subtropical environment. The Cardy Nitrate Meter may also be of use in providing a quick and easy estimate of soil N availability.

The objective of this study was to evaluate the effectiveness of the Minolta SPAD 502 Chlorophyl Meter and the Cardy Nitrate Meter for rapid and easy determination of N status of the crop, and N availability in the soil in a subtropical environment.

MATERIALS AND METHODS

Measurements were taken in conjunction with a sugarcane (*Saccharum officinarum* L.) nutrition and water stress study that was being conducted at the Texas A&M Research and Extension Center at Weslaco on a Raymondville clay loam soil (fine, mixed, hyperthermic Veric calciustolls). Cultivar CP70-321 was planted in 1990 and received treatments consisting of 4 levels of N fertilizer application and 5 moisture stress regimes, for a total of 20 treatments replicated 4 times in plots 9.15 m wide (six 1.52 m rows) by 15.25 m in length. Nitrogen fertilizer was applied at rates of 0, 60, 120 and 180 kg N ha^{-1} yr^{-1}; and moisture stress was imposed by withholding irrigation during one of 4 different 6-wk growth intervals, or as an unstressed check. The measurements reported in this study were taken in all plots in the spring of 1995 between the 3rd and 4th ratoon crops, prior to fertilizer application to the 4th ratoon crop.

Two types of measurements were made on plant leaves. Chlorophyll measurements were taken using the Minolta SPAD 502 Chlorophyll Meter on 3 Feb and 27 Mar by averaging the readings from 8 randomly selected plants in each plot at each date. Chlorophyll reading were taken on the uppermost fully expanded leaf, midway between the base and the tip of the leaf, and midway between the outer edge and midrib. Leaf sap NO_3^--N measurements were taken using the Cardy Nitrate Meter on 27 Mar by selecting the uppermost fully expanded leaf from a single randomly selected plant, separating the midrib from the rest of the leaf, and squeezing out the sap using a hand-held press. Measurements were made in each plot in triplicate and averaged together.

Soil samples, obtained on 7 Feb by taking soil cores to a depth of 15 cm in the middle of the bed from several randomly selected locations within each plot and mixing the samples together for each plot, were air-dried and ground. Soil NO_3^--N readings were made using two different procedures. Cardy soil NO_3^--N readings were taken using a 1:1 (v:v) soil:extractant containing 20 ppm NO_3^--N. Readings were corrected to adjust for the nitrogen in the extracting solution. "Wescan" soil NO_3^--N readings were taken using a 1:10 (w:w) soil:extractant consisting of 2 N KCl. A Wescan Model 360 Ammonia Analyzer (Alltech Associates, 2051 Waukegan Road, Deerfield, IL 60015, USA) which reduces NO_3^- to NH_4^+ using a Zn catalyst, separates the NH_4^+ using a selective ion membrane, then determines NH_4^+ concentration using electrical conductivity, was used as the laboratory reference instrument.

Sugarcane yields were determined at the end of the growing season by first burning the field to remove dry leaf material, then hand harvesting and weighing all cane from a 41.8 m^2 area from the center of each plot.

All data were analyzed statistically using the GLM procedure of PC SAS (SAS Institute Inc., 1988) which allows both discrete and continuous variables in the same model. No statistically significant effects due to moisture stress regimes were found on any analytical plant or soil measurement taken. Moisture stress significantly affected cane yields, but there

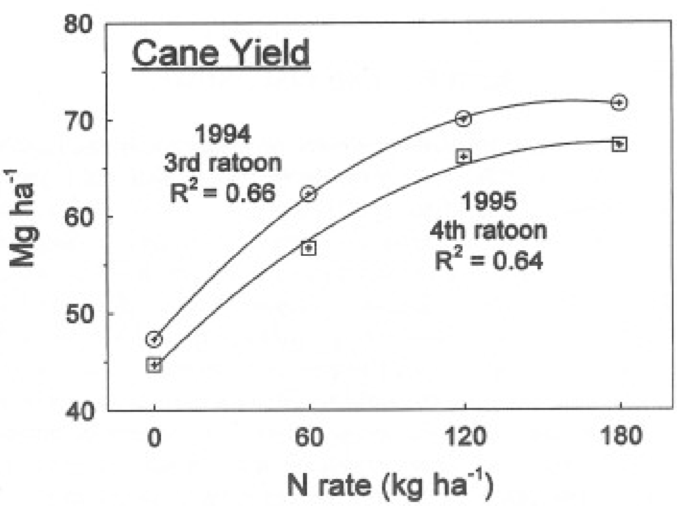

Fig. 1. Third and fourth ratoon sugarcane yields as affected by different levels of N fertilizer application. Highly significant quadratic correlations were found between yield and N application rate.

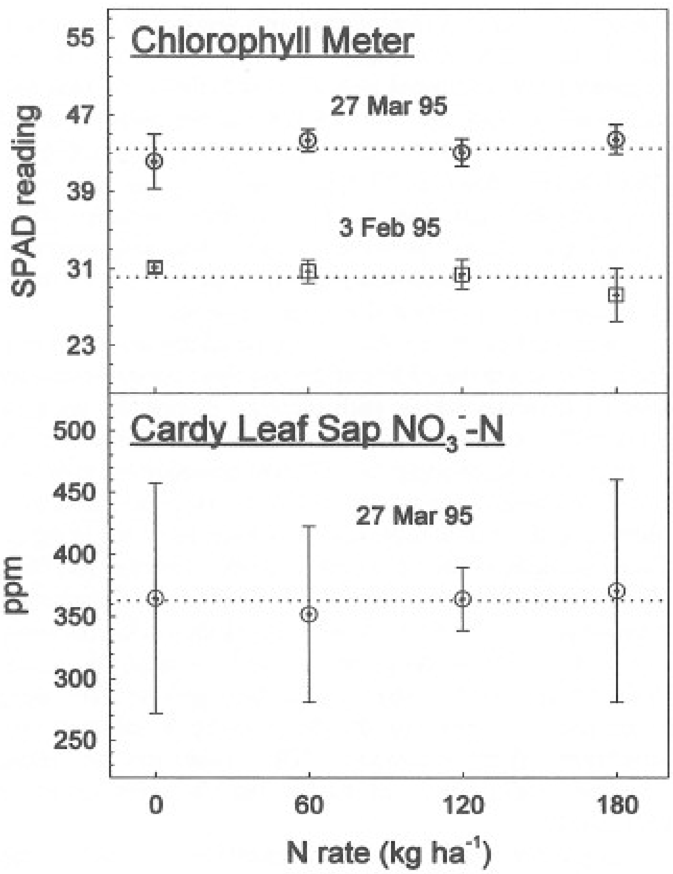

Fig. 2. Minolta SPAD 502 Chlorophyll meter readings on two dates, and Cardy leaf sap NO_3^--N on one date, on a 4th ratoon sugarcane crop at different levels of N fertilizer application. No statistically significant correlations were found between the parameters measured and N fertilizer application rates. Error bars represent 95% confidence intervals for the means.

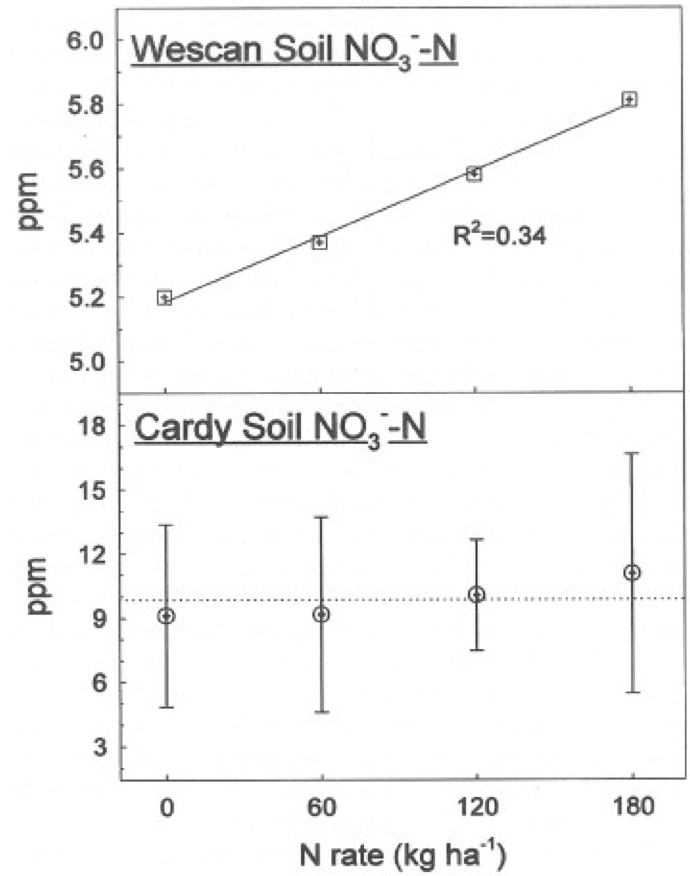

Fig. 3. Soil NO_3^--N levels as determined by the Wescan Ammonia Analyzer and the Cardy Nitrate Meter for different levels of N fertilizer application. A significant linear correlation was found for Wescan soil NO_3^--N, but no significant linear or quadratic correlation was found for Cardy soil NO_3^--N. Error bars represent 95% confidence intervals for the means.

were no significant interactions between N application rate and moisture stress. Therefore, data reported herein was averaged across moisture stress treatments, and only N application is considered.

RESULTS AND DISCUSSION

Numerous fertilization studies on sugarcane in the Lower Rio Grande Valley of Texas have shown that cane yield responses to N fertilizer application are very low in the first crop harvested, and tend to increase with each successive ratoon crop over a wide variety of conditions (Rozeff, 1990). In this study, both the 3rd ratoon sugarcane crop grown during 1994 and the 4th ratoon crop grown during 1995 showed significant quadratic yield responses to increasing rate of N application (Fig. 1). It would therefore seem very likely that the sugarcane crop in the spring of 1995 had differences among the different N fertilizer treatments in the N nutritional status in the crop, and/or in the N supplying capacity of the soil.

Measurements taken with both the Minolta Chlorophyll Meter and the Cardy Nitrate Meter failed to indicate any differences among the N fertilizer treatments in plant N nutritional status (Fig. 2). When the first SPAD measurements were taken on 3 Feb, very little new growth had occurred, and the few leaves present were pale and desiccated due to the poor growing conditions that had occurred up to the time of sampling. The second SPAD measurements and the Cardy leaf sap NO_3^--N measurements were taken 52 days later when the the crop was almost at the point of being too large for ground fertilizer application equipment to be used. At this time the crop was much greener as indicated by the higher average SPAD readings on the second sampling date compared to the first, but again no significant differences due to the N fertilizer treatments were found.

Soil NO_3^--N levels measured by the Wescan Ammonia Analyzer showed a significant linear increase with increasing N application rates (Fig. 3), although the increase was only .0034 ppm per kg of N applied. Soil NO_3^--N levels measured by the Cardy Nitrate Meter showed no significant relationship with N application rates, even though there appeared to be greater differences between N application levels for the Cardy measurements than for the Wescan measurements. The coefficient of variation for the relationship between N application rate and Cardy soil NO_3^--N was 50.8%, whereas between N application rate and Wescan soil NO_3^--N it was 13.5%.

CONCLUSIONS

The results of this study indicate that neither the Minolta SPAD 502 Chlorophyll Meter or the Cardy Nitrate Meter would be useful tools for predicting N fertilizer requirements for sugarcane in the subtropical Lower Rio Grande Valley of Texas. Neither instrument indicated any difference in the N nutritional status of the crop. The lack of active plant growth at the time the measurements were made, and therefore the small amount of N that had been taken up to that point, resulted in no differences in the N nutritional status of the crop at the time of sampling. Sugarcane is a high biomass crop that has its greatest N uptake during the rapid growth phase in July. However, fertilizer applications must be made no later then early April. The Cardy Nitrate Meter also failed to detect any significant differences in N availability in the soil due to supplemental N fertilizers, even though soil NO_3^--N differences were found using the Wescan Ammonia Analyzer. Variability in the Cardy measurements apparently reduced the reliability of this instrument for detecting such differences in sugarcane.

The results of this study with sugarcane may not be indicative of the results that might be obtained for other crops including fruits and vegetables grown extensively in this region, as suggested by various other published reports. A wide range of crops grown in the Lower Rio Grande Valley need to be tested in the future.

Several researchers have suggested a normalization procedure for using the chlorophyll meter to assess the need for N fertilizer consisting of comparing measurements taken throughout a field to those taken in a small reference strip which has received enough N fertilizer to assure that N is not deficient, but in all other respects has received the same management inputs as the rest of the field (Peterson et al. 1993, Minotti et al. 1994). This and a consistent sampling protocol might reduce variation in SPAD readings caused by factors other than N status.

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